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R W DRISKO ET AL. OCT 82 NCEL-TN-1647

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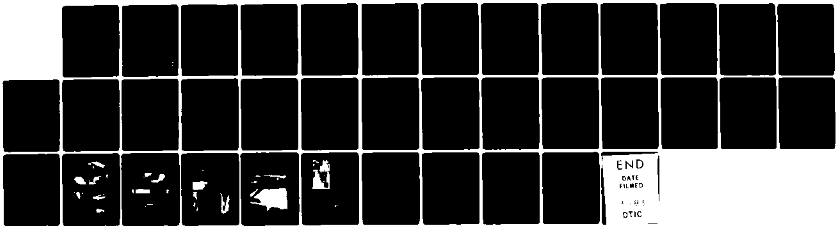

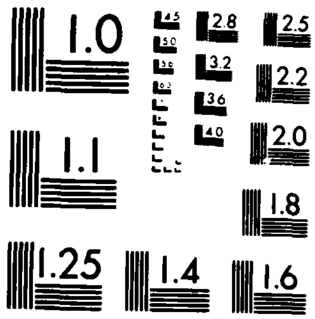

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AUTHOR: R. W. Drisko, T. B. O'Neill, and J. R. Moses

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NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

METRIC CONVERSION FACTORS

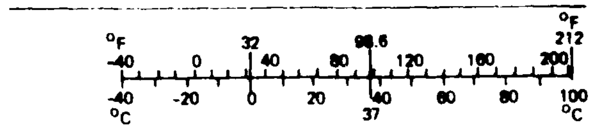
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, *Units of Weights and Measures*, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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A survey was made of mildew problems at selected Naval activities in Hawaii and the Western Pacific. A list of factors affecting mildew growth was developed along with recommended practices to control the growth. A list of EPA-approved mildewcides is presented.

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INTRODUCTION

Microbial defacement and deterioration of organic coatings occur at Naval installations around the world. Although destructive microbes deface buildings at most locations (e.g., Naval Weapons Station Yorktown, VA, Figure 1), they are especially prevalent at tropical and subtropical locations. Economic effects to the Navy have never been determined, but losses caused by microbiological attack on paints and paint films in the United States have been conservatively estimated to exceed $1 million annually (Ref 1). These cost figures do not include damage to substrates such as communications equipment, utilities, etc., which would greatly increase this estimate. Thus, the total annual damage probably exceeds several million dollars. Also of importance is the increasing awareness of the relationship of mildew to serious, chronic health problems (Ref 2). Many individuals are hypersensitive to airborne fungal parts (e.g., hyphae and spores) which, upon inhalation, act as allergens producing hypersensitivity pneumonitis. Of the fungal genera cited in this report, *Aspergillus*, *Aureobasidium*, *Cladosporium*, and *Alternaria* have been identified as allergens. *Aspergillus* is also associated with aspergilloma (fungus balls consisting of fungal parts in bloody sputum). *Fusarium*, also identified in this study, can, upon contamination of the eye, cause blindness.

After a recent tour of Navy facilities in the Western Pacific, the Chief of Naval Operations (CNO) expressed to the Commander of the Naval Facilities Engineering Command (NAVFAC) his concern about the unsightly appearance of both the interiors and exteriors of buildings caused by microbiological organisms. As a result, the Pacific Division (PACDIV) of NAVFAC and the Naval Civil Engineering Laboratory (NCEL) were directed by NAVFAC to determine the causes of these problems and prepare recommendations for both preventive and corrective actions. This report describes a tour by PACDIV and NCEL personnel in Hawaii and the Western Pacific area and their findings and recommendations.

BACKGROUND

Many different species of microorganisms can be found on painted and unpainted surfaces in tropical and subtropical locations (Ref 3, 4, and 5). Those causing the greatest discoloration are fungi with dark pigmentation that render them most conspicuous. These include the black mold, *Aureobasidium pullulans* (formerly called *Pullularia pullulans*) and *Cladosporium herbarum* (Ref 3 and 4), and the blue-green alga *Oscillatoria* (Ref 5).

Microbiological deterioration of paint has been classified (Ref 6) into two basic categories. The first category is the spoilage of liquid paint (usually emulsion paint) usually by bacterial attack (Ref 7 and 8), which results in putrefaction and general breakdown of the paint. The second consists of microbiological attack on cured paint films. The present investigation was restricted to the latter category.

Fungal growth on painted surfaces is highly dependent upon the nature of the substrate (Ref 9). This is believed to be related more to the effect of the substrate on the environment (i.e., pH and retention of moisture) than to providing nutrient for growth. Thus, fungal growth is generally the greatest on painted wood (which has a high moisture retention and a suitable pH) and the least on painted metal and concrete. The infrequent occurrence of fungi on concrete or asbestos cement siding is primarily related to the characteristic alkalinity of these surfaces. Fungal growth is greatly restricted where the environment exceeds a pH of 8.5. Microorganisms grow the fastest in damp, shady locations.

The nature of the paint is also an important factor affecting fungal growth. Of the three basic components of paint, the solvent is not a factor in dried films because it evaporates on curing; the pigment may inhibit growth by being toxic or by producing an alkaline environment; and the organic binder may serve as a source of nutrient. There have been many reports of fungal metabolism of paint binders containing drying oils (e.g., alkyd).

Spores of microorganisms are spread from soil and other sources by air currents. The experiences of NCEL (Ref 3) and others indicate that air currents may favor the deposition of spores on specific areas of a building, depending upon prevailing wind direction and building configuration. Surface texture and paint softness are also factors in the collection of spores (Ref 10). The more textured a surface, the greater the retention of contaminating spores, soil components, and organic matter which serve to support microbial growth. Similarly, contaminants are more likely to be retained on a soft or tacky paint rather than a hard, smooth one.

Mildewcides or mildewstatic agents are generally added to paints to control mildews where their growth is expected to be a problem. Some of these materials must be dispersed into the resin during production of the paint, while others can be added anytime prior to paint application. Two pigments that impart mildew resistance are zinc oxide (a fungistatic agent) and barium metaborate. They are active pigments (especially the zinc oxide) in that they may react with the vehicle portion of the paint unless special care is taken in the formulation. Other disadvantages associated with barium metaborate include possible reductions in paint gloss and opacity (Ref 11).

Mercury-containing mildewcides have been extensively used in the past because of their relatively low price and high toxicity to a wide spectrum of organisms. Concerns about the risks associated with various man-made mercury compounds, especially the neurological effects of methylated (alkyl) mercury if it accumulates in the brain of humans or other organisms, led the Federal government in 1969 to initiate a series of regulatory actions against mercury pesticides. In 1974, the Environmental Protection Agency (EPA) commenced administrative hearings to consider the benefits and the disadvantages of mercury pesticides with the possibility of prohibiting their use. Following these hearings, the final determination of the Administrator allowed for continued use of mercury pesticides for a limited number of purposes. The permissible uses include mercury pesticides as an in-can preservative in water-based paints and coatings, and as a fungicide/mildewcide in water-based paints and coatings for exterior applications only.

The EPA has registered numerous nonmercurial fungicides (proprietary formulations containing approved chemicals) for use in paints. The labeling of each individual product bears the appropriate directions for use, precautionary statements, and restrictions to ensure proper use. Registration only certifies acceptance from an environmental standpoint and does not consider the efficiency of such materials in controlling the growth of microorganisms. Studies have been conducted on the performance of mildewcides in various paints (Ref 1, 11, and 12) and stains (Ref 13).

It is important to remove completely all mildew before repainting a surface in order to prevent residual organism attack of the new coating. Reference 10 (Paragraph 10.3.2.5) describes how a solution of bleach, detergent, and trisodium phosphate should be used to kill the existing organisms and remove them from the surface to be painted.

FINDINGS OF FACILITIES INSPECTION

Two of the authors (Drisko, a coating specialist at NCEL, and Moses, a maintenance engineer at PACDIV) visited selected activities in Hawaii and the Western Pacific area (see Table 1) to (1) determine the nature and extent of mildew defacement and (2) factors contributing to it. At each activity, sterile cotton-tipped swabs were rubbed over selected surfaces and streaked on plates of microbial media. The areas investigated included painted and unpainted and interior and exterior surfaces. Most of the latter were of concrete. Two different microbial media were used, Sabouraud's agar and trypticase soy agar. Sabouraud's agar is an acidic medium (pH 5) that contains large amounts of dextrose as well as organic nitrogen for the isolation and growth of fungi; trypticase soy agar is a neutral medium without significant amounts of sugar that is used for the isolation and growth of bacteria. The plates were incubated at ambient temperatures (subject to variations during mailing) for a period of 1 to 2 weeks. From the mixed cultures that appeared during incubation, isolates were transferred to appropriate media, incubated at 25°C, and subsequently identified.

Algae, which were also believed to be present on discolored surfaces, grow slowly and do not compete well with fungi and bacteria on agar plates. Thus, dry samples from Guam which were suspected to contain algae were collected by scraping and sent separately for laboratory identification by the NCEL microbiologist. When examined microscopically they appeared to contain only algae. However, when streaked on Sabouraud's and trypticase soy agar, the same microorganisms found in direct streaking were isolated.

Results of the laboratory identification are summarized in Tables 2 and 3. Because of the limited sampling, only generalizations can be made. Aureobasidium was found on exterior exposures at all four geographical locations and was found more frequently than any other genera. Findings were also consistent with the report (Ref 14) that Aureobasidium is the most common mold of exterior surfaces, and Cladosporium is the most common mold of interior surfaces Numerous organisms other than fungi were present. Fungi were present in all growths visually identified as mildew, and algae predominated in all growths visually identified as algal. The algal growths called black were predominantly blue-green algae; the algal growths called green contained green and

blue-green algae; and the algal growths called red were ironically caused by the green alga, Gongrosira. Many of its cells had formed the red pigment haematochrome (in response to a high intensity of light) which masked the green chlorophyll. This explains why such growths turned yellow when rubbed with a wet finger. Reference 15 reported the common occurrence of the blue-green alga, Oscillatoria and its appearance as a blackish growth. The occurrence of a rotifer (Philodina) in one sample suggests that the sample was taken from a moist area close to the ground.

In order to determine if the microorganisms found in the Pacific Ocean areas are similar to those that deface Navy buildings on the Gulf Coast, specimens were removed from buildings at NAS, Pensacola and Tyndall Air Force Base. The microorganisms identified are listed in Tables 4 and 5. They are quite similar to those found in Pacific Ocean areas and in Puerto Rico (Ref 3 and 4). It is significant that Cladosporium was found in all seven specimens taken.

Table 2 through 5 indicate that both fungi and algae must be controlled to prevent microbiological defacement of buildings. Reference 15 states that one cannot assume a biocide effective in controlling fungi can also effectively control algae and vice versa.

General Observations

At each of the four geographical locations listed in Table 1, the types of mildew defacement appeared visually to be of three basic types but of different intensities. The first type, a heavy black growth believed to be algal (blue-green algae), was found on the facia of painted and unpainted concrete buildings and other exterior areas (especially shady areas) where water drained across the surface (Figure 2). It was also found on dry, aged concrete buildings and pavements. Many facia of buildings at Guam were painted black to obscure the subsequent black defacement. The second type was a black fungal growth believed to be caused by Aureobasidium pullulans that was found on interior (Figure 3) and shaded exterior painted surfaces in more discrete colonies. The third type (Figure 4) believed to be red and green algal growths was found much less frequently on painted surfaces. The red growth turned yellowish when streaked with a wet finger (dark "+" in Figure 5).

The interior mildew problems were attributed to the use of fan-coil chilled-water air conditioners (FCU) and partial or intermittent air conditioning in living spaces. The infiltration of air through open windows and doors further aggravate the problem of moisture removal. FCU's were used in Unaccompanied Enlisted Personnel Housing (UEPH) and Unaccompanied Officers Personnel Housing (UOPH) at Subic Bay and Okinawa as well as in selected buildings at Guam.

Another problem associated with air conditioning was the occurrence of "thermal bridges." These occurred on exterior and hallway surfaces of poorly insulated buildings where heat-conducting components extended through the buildings envelope to link these surfaces with air conditioned surfaces. The surfaces were often cooled below the dew point to permit moisture condensation.

Mildew defacement was greatest at Guam where most occurred on exterior surfaces, but some was also found on interior walls, plastic cushions (Figure 6), and other surfaces at the Navy hospital and two

chapels. These interior growths are believed to be related to inadequate air conditioning with FCU's. Mildew was prevalent in air-conditioned rooms behind large items of furniture where air circulation was restricted. Their growth is presently controlled by periodic washing with vinegar and water.

The lesser amount of mildew at Subic and Cubi was believed to be related to (1) more frequent repainting, (2) more frequent washing, and (3) a prolonged dry season. Mildew was found on numerous painted exteriors as well as canvas awnings (Figure 7) and interiors of quarters. The latter was attributed by local personnel to inadequate air conditioning from FCU's which are gradually being replaced by central air conditioning. At Cubi, water blasting (700 psi) has done a good job of removing mildew and loose paint from building exteriors before repainting. Some of the exterior mildew was related to the occurrence of thermal bridges.

At Okinawa, mildew was found on the exterior of quarters in shaded areas, damp areas such as under exhaust vents, and on roof facia, but interior defacement of acoustical ceiling tiles (Figure 3) in quarters was a much greater problem. In UEPH buildings, moisture condensation had occurred on air conditioning piping running between the roof and the suspended ceiling and had then been retained by the insulation. From the saturated insulation, it dripped onto suspended ceiling tiles. These problems were again attributed by local personnel to an ineffective system utilizing FCU air conditioners which are being replaced. At all locations, more mildew was generally on the shady side of buildings.

The much lesser amounts of mildew found in Hawaii were related to the much milder conditions. Strangely, Hawaii is reported to be devoid of mildew (Ref 1). It is, however, a prevalent problem in all areas where heavy rainfall causes dampness to be retained on building exteriors.

Paint Practices

At each activity visited, an attempt was made to identify the types of paint used to determine the possible relationship of paint type (generally either alkyd or latex) to mildew growth. This was done both by referring to records of materials used and by spot sampling for later laboratory analysis. To avoid damaging sound paint, sampling was done most frequently on blistering or peeling paint. The results of the sample analyses are shown in Table 6. At each activity most of the buildings were made of concrete, and thus most of the paint was latex. Several activities are adopting the practice of using a textured paint (i.e., TT-C-555) on concrete building exteriors. These paints are available as either an alkyd or latex formulation. Although no statistical analysis could be made, it was apparent that mildew growth occurred on both types of paint. This is in agreement with the generally accepted idea that the chief function of the substrate (painted or unpainted) in mildew growth is to provide a surface that retains spores, dirt, organic matter, and moisture (thus, facilitating growth) and that paint (e.g., drying oils in paint) is not necessary to provide nutrients. Nevertheless, a few paint suppliers still believe that it is necessary to add mildewcide only to oil base paints because latex paints do not support growths. Even stranger is the general note in Reference 16 for recoating interior concrete walls: ". . . in areas where profuse mildew growth has occurred, water based paint should not be used since mildew has reoccurred even with the addition of mildewcide."

The Public Works Officer at Commander Fleet Activities (CFA), Okinawa, Japan, requested some recommendations for preventing latex paint from peeling from concrete. Because this appeared to be a rather widespread problem at the tropical location visited, these recommendations are included as the Appendix to this document.

Factors Affecting Mildew Growth

The Background section of this report cites several factors that contribute to mildew growth. During the inspection of the facilities on this tour most of these and other factors were found to be significant; see Table 7 for a summary.

Weather. Weather is certainly one of the chief factors affecting mildew presence and activity. Fungi are most abundant in tropical areas where high temperatures and moisture greatly promote growth. These conditions are, in large part, responsible for the greatest microbial growth found on Guam. Reference 7 states that fungi grow best on damp, warm, and poorly ventilated surfaces devoid of sunshine. Ultraviolet light from the sun usually kills bacteria, but fungi can tolerate high levels of sunlight. Bacteria, however, grow in shaded areas under paint films or fungal growths exposed to light. Thus, the "preference" for shade may be related more to retention of dampness, lower temperature, and the presence of a protected area. Mildew was frequently found under awnings (Figure 8) and roof eaves. The moisture required for growth is frequently produced by condensation on the exteriors of poorly insulated walls when the interiors are cooled by air conditioning (Ref 17 and 18). Similarly, condensation can occur under horizontal building projections when cooling lowers the temperature below the dew point.

Prevailing Air Currents. The extent of the effects of prevailing air currents preferentially carrying microbial contaminants to certain areas on buildings was not clearly apparent during the inspection because of the unknown effect of adjacent structures on local currents. During the exposure of painted wooden panels on a rack in Puerto Rico (Ref 19), it was discovered that the location of the panels on the rack has a significant influence on the magnitude of microbial growth. Thus, it was necessary to have the test paints replicated and randomized during the exposure to avoid localized wind effects. At all locations visited on this tour, mildew was most readily found under eaves and covered walkways, and behind structural configurations that resulted in restricted air movements. Lower temperatures may also occur in the interior corners of air-conditioned buildings because of the difficulty of insulating these areas.

Building Design. The most obvious deficiencies in building design that accelerate mildew growth were those allowing water to drain over roof facia or down the walls. Mildew was commonly found where moisture dripped from air conditioners (Figure 9). Fortunately, these can usually be corrected with relative ease. Also, wooden surfaces retained dampness longer than concrete surfaces.

Surface Condition. The effect of surface roughness on promoting mildew growth was noted on several building exteriors. On one, there was growth on a corrugated surface, but none on an adjacent smooth surface coated with the same paint. At another location growth occurred on a concrete surface covered with a textured coating but not on an adjacent area coated with a smooth paint. At a third location (Figure 10), more growth was on localized wrinkled areas of alkyd paint over corrugated steel than in adjacent smooth areas.

Painting Practices. A few deficiencies were also noted in painting practices. These included incomplete kill and removal of mildew before repainting, painting under adverse conditions such as wind and rain, and poor choice of paints for a particular environment or service. Any surface deterioration of a paint promotes even greater retention of microorganisms and consequently greater deterioration. Alkyd and other modified drying oil paints may be slow drying, depending upon the amount (commonly called oil length) of oil they contain, and thus retain tackiness for 1 or more days. If applied too thickly (more than 3 mils wet film thickness) on hot days, they may have surface drying but remain soft under the surface skin, resulting in wrinkling.

At one location, additional mildewcide was added to both oil and latex paints prior to application. Obviously, both the type and the amount of mildewcide in a paint will determine its effectiveness and permanence in paint.

Air Conditioning. Most interior mildew is related to air conditioning practices that do not dehumidify closed areas adequately. These problems are discussed extensively in References 17 and 18 as is the persistent problem of FCUs inability to control humidity within the comfort zone. NAVFAC DM-11-1 (Ref 20) states that FCUs should not be used in tropical areas.

AVAILABLE EPA-REGISTERED MILDEWCIDES

Many EPA-approved proprietary mildewcide compositions containing toxicants are available for incorporation into paints. Table 8 lists acceptable chemical toxicants; Table 9 lists EPA-approved mildewcides; and Table 10 lists names and addresses of the suppliers. Table 8 was prepared from data supplied by EPA, and Tables 9 and 10 from data received from 11 responses to letters sent to 27 suppliers who were known to sell mildewcides at one time. Tables 8 and 9 do not contain all possible entries nor can it be assumed that all entries cited will continue to maintain approval. The data in the tables are presented for information only, and specific recommendations for use of listed products should be obtained from the suppliers. Again, EPA-approval is related to environmental acceptability and not to efficacy. Nonmercurial mildewcides for paints cost considerably more than mercurials (Ref 21).

Some mildewcides must be dispersed into the paint by the supplier, while others can be added to the paint immediately before application. Dispersing significant amounts of mildewcide into a paint usually limits the extent to which formulations can be varied and may alter the physical

and/or chemical properties of the paint. It does, however, insure that the mildewcide is added and may provide a larger reservoir of toxicant. Addition of mildewcide by the painter immediately prior to painting provides freedom in determining the type and amount to use.

Most specifications for latex paints have a requirement for resistance to fungal growth, while those for alkyd paints do not. The requirement is a resistance to 1 to 3 selected microorganisms on an agar culture medium (Ref 22) or in a laboratory environmental chamber (Ref 23). Paint suppliers do not ordinarily run these tests on batches of paint, but merely add mildewcides certified by the manufacturer to impart the required level of resistance. NCEL studies (Ref 19 and 24) have shown that results from these procedures frequently relate poorly to actual resistance under field exposure.

RECOMMENDATIONS

Field Practices

The following recommendations are made for use in the field.

1. Design or modify drainage systems for roofs of buildings to prevent water (a) from running off the roof and down the building's sides and (b) from ponding on the roof or other building components.

2. Design or modify airconditioning systems to prevent water from running down the walls of the building.

3. Design wall and roof insulations to maintain, as far as possible, exterior surface temperatures above the dew point. Avoid "thermal bridges," i.e., heat-conducting components that extend continuously through the building's envelope.

4. Design or modify buildings to avoid structural projections that result in wind-sheltered surfaces.

5. Upgrade air conditioning systems to achieve the desired level of humidity with the necessary circulation to control all areas. Because fan-coil chilledwater air conditioners are ineffective in removing moisture, they should not be used in tropical areas (Ref 20). Extensive recommendations on air conditioning are presented in References 17 and 18.

6. Keep massive pieces of furniture away from walls to permit air circulation behind them.

7. Utilize insulating materials, such as foamed glass or plastic, that will not retain large amounts of moisture.

8. Minimize the number of trees near buildings to eliminate shaded areas.

9. When cleaning a surface to be repainted, follow the procedure given in Paragraph 10.3.2.5 of Reference 10. This calls for scrubbing with a solution consisting of 3 ounces (2/3 cup) trisodium phosphate, 1 ounce of household detergent, 1 quart of 5-1/4% sodium hypochlorite

solution (commercially available in many household bleaches), and 3 quarts of warm water. Rubber gloves should be worn to protect the workers hands from the harsh solution. An alternative to this procedure is removal by waterblasting at 700 psi, followed by rinsing with a solution consisting of 1 quart of 5-1/4% sodium hypochlorite and 3 quarts of water to kill any residual organisms.

10. When cleaning a surface for purposes other than repainting, use a mildew-scrubbing solution. Thus, the above solution should be used without the trisodium phosphate since it can harm the paint. A small test area should first be cleaned to see if the hypochlorite causes significant bleaching of the paint. If it does, then the hypochlorite should also be omitted as more dilute concentrations will not effectively kill mildew microorganisms, and the surface should be cleaned with detergent and water.

11. Apply paint only when temperature and humidity are satisfactory, i.e., within the range specified by the coating supplier and at least 5°F above the dew point.

12. Minimize moisture migration through walls by using a moisture-resistant coating on the exterior and a "breathing" coating (e.g., latex) on the interior wall.

13. Avoid long oil formulations of alkyd paints that remain soft or retain tackiness for more than 24 hours. To accelerate complete drying of the entire paint film, apply no more than a 3-mil dry film thickness in one coat.

14. Avoid rough surfaces where possible. For a textured coating, use a material with a few large particles rather than many fine particles to minimize the total surface area.

15. Specify paints with a mildewcide added by the manufacturer, or add an EPA-approved mildewcide just prior to paint application. Reference 4 has such a list.

16. Follow the paint practices recommended in Reference 10 to minimize chalking, erosion, blistering, peeling, and other types of paint deterioration.

<u>Future Work</u>

The following are recommended for further study, development, or other action to provide practical information for field activities.

1. An engineering investigation to determine (a) efficacy of selected EPA-approved mildewcides in latex and alkyd paints receiving exterior tropical exposure, (b) efficacy of using accelerated laboratory tests in predicting exterior field performance and length of effectiveness of mildewcides, (c) relative importance of surface texture in

mildew control, (d) relative lengths of efficacy of mildewcides comprising a significant portion of the paint pigment as compared to those added in small amount, and (e) criteria for effective use of mildewcides in order to prepare guidance for field use.

2. A quick test that verifies mildewcide has been added to paint, including a test for mercurials.

3. Determination of the extent to which mildew growing on building interiors affects the health of occupants.

4. An NCEL techdata sheet for dissemination to field activities and incorporation along with other appropriate information in NAVFAC coating workshops, especially those held at tropical and subtropical locations.

5. Greater utilization of NCEL and EFD personnel with expertise in mildew control by field activity, both at design stages and after problems have been identified. These experts may be able to provide information when they are on official travel in these areas.

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Table 1. PACDIV Activities Inspected for Mildew

Location	Activity
Hawaii	Naval Communication Area Master Station EASTPAC Wahiawa
Guam	U. S. Navy Public Works Center U. S. Naval Station U. S. Naval Air Station Agana U. S. Naval Hospital U. S. Naval Communication Area Master Station WESTPAC Finegayan
Philippines	U. S. Naval Station Subic Bay U. S. Naval Air Station Cubi Point
Okinawa, Japan	Commander Fleet Activities/U. S. Naval Air Facility, Kadena

Table 2. Nonalgal Microorganisms From PACDIV, Isolated from Streaked Culture Media

Microorganism	Sample Identification[a]									
	Hawaii		Guam				Philippines		Okinawa	
	H-E-1	H-E-2	G-E-1	G-E-2	G-E-3	G-I-4	P-E-1	P-I-2	O-E-1	O-I-2
Molds										
<u>Alternaria</u>						x				x
<u>Aspergillus</u>		x	x	x						
<u>Aureobasidium</u>	x	x	x				x		x	
<u>Cladosporium</u>					x	x	x	x		
<u>Fusarium</u>		x							x	
<u>Penicillium</u>				x			x			
<u>Helminthsporium</u>		x		x	x		x			
Yeasts										
<u>Rhodotorula</u>		x		x						
<u>Torula</u>	x	x		x						
Bacteria										
<u>Actinomyces</u>							x		x	
<u>Alcaligenes</u>				x				x		
<u>Bacillus</u>				x						x
<u>Flavobacterium</u>	x							x		x
<u>Micrococcus</u>				x						x
<u>Pseudomonas</u>										x
<u>Streptomyces</u>										

[a] E = Exterior; I = Interior

Table 3. Algal Microorganisms[a] Found on Building Exteriors at Guam

Algal Organism	Sample Color	Sample Number				
		1	2	3	4	5[b]
Green						
Desmococcus	Green		xx			
Gongrosira	Red	xxx			xxx	
Blue-Green						
Microcoleus	Black			xxx		xxx
Oscillatoria	Black			xxx		xx
Phormidium	Green		xx			
Symploca	Black			xxx		xxx
Synechococcus	Red	x				

[a]Number of x's indicates relative abundance.
[b]The rotifer *Philodena* found in large numbers in Sample 5.

Table 4. Nonalgal Microorganisms From Florida, Isolated from Streaked Culture Media

Microorganism	Sample Identification[a]						
	Pensacola					Tyndall AFB	
	P-E-1	P-E-2	P-E-3	P-I-4	P-I-5	T-E-1	T-E-2
Molds							
Alternaria					x	x	
Aureobasidium	x	x					
Cephalosporium						x	
Cladosporium	x	x	x	x	x	x	x
Scopulariopsis	x						
Verticillium	x		x				
Yeasts							
Rhodotorula			x				
Bacteria							
Alcigenes	x	x		x	x		x
Bacillus			x				
Flavobacterium	x	x				x	x
Micrococcus	x	x					x
Pseudomonas			x				
Streptomyces						x	

[a]E = Exterior; I = Interior

Table 5. Algal Microorganisms Found in Florida

Algal Organism	Sample Color	Sample Identification[a]							
		Pensacola							Tyndall AFB
		P-E-1	P-E-2	P-E-3	P-I-4	P-I-5	P-E-6	P-E-7	T-E-1
Green									
<u>Desmococcus</u>	Red	x				x	x	x	
Blue-Green									
<u>Chlorococcum</u>	Green/Black								x
<u>Chroococcus</u>	Green/Black						x		
<u>Oscillatoria</u>	Green/Black	x	s[b]	s	s	s	x	x	
<u>Phormidium</u>	Green/Black						x		

[a]E = Exterior; I = Interior

[b]= Slight growth

Table 6. Description of Paints Sampled

Geographical Location	Substrate	Paint Type	Extent of Mildew[a]	Condition of Paint
Wahiawa, Hawaii	wood	latex	slight, localized	Good
Guam				
Public Works Center	corrugated steel	alkyd	extensive	Generally good
NAVSTA Housing	concrete	latex	none (just applied)	Peeling from smooth concrete
NAVSTA Gym	concrete	latex	extensive	Localized cracking and peeling
NAVSTA Dental Clinic	concrete	alkyd	moderate	Good
Hospital BEQ	concrete	textured latex	slight, localized	Localized peeling
Hospital Fire Station	concrete	latex	none	Localized peeling from smooth concrete
NAVCAMS Bowling Alley	concrete	textured latex	moderate	Localized blistering
Subic Bay				
BOQ	concrete	latex	slight, localized	Localized peeling from smooth concrete
Kadena, Okinawa				
White Beach Bowling Alley	concrete	latex	slight, localized	Localized peeling from smooth concrete

[a]Rated subjectively. Mildew is nonuniform and concentrated in damp to shady areas or ones behind baffles where spores are deposited by winds.

Table 7. Factors Affecting Mildew Growth on Exterior and Interior of Buildings

Category	Factor	Effect
Weather	Temperature	Greater growth at higher temperature
	Rainfall and humidity	Wetness promotes growth
	Solar radiation	Light inhibits bacterial growth
	Wind direction and intensity	Wind carries spores and dirt to building
Building Design	Roughness of surface	Rougher surfaces pick up more spores and dirt
	Roof overhang to impart shade	Fungi grow best in shade
	Poor drainage	Permits prolonged dampness
	Effect of building substrate	Wood retains moisture; concrete imparts alkalinity etc.
	Building orientation	Weather affects building adversely
	Area configurations	Deposition of wind-borne dirt and spores and retention of moisture
	Insulation	Prevents heat transfer between wall interiors and exteriors
	Air handling[a]	Effective air exchange and humidity control
Paint Formulation/ Practices	Paint texture	Roughness effect in building design
	Tackiness	Tacky paints pickup and retain more dirt and spores
	Presence of drying oils	Microorganisms may use oil as food
	Mildewcides	Toxicity and amount relate to effectiveness
	Extent of mildew removal before repainting	Incompletely removed mildew can infect new paint
	Practices leading to early paint deterioration	Cracked and peeling paint pick up more spores, dirt, and moisture

[a]Interior only

Table 8. Chemical Compounds Acceptable for Compounding into Mildewcides*

Di(phenylmercury) dodecenylsuccinate**
Phenylmercuric acetate**
Phenylmercuric borate**
Phenylmercuric oleate**
n-alkyl dimethyl ethylbenzyl ammonium cyclohexyl sulfamate trans-1,2 bis (propylsulfonyl) ethene
Bis(tributyltin) oxide
Captan
Chlorothalonil (also called tetrachloroisophthalonitrile)
Parachlorometaxylenol
Diiodomethyl-p-tolylsulfone
3-Iodo-2-propynyl butylcarbamate
2-*n*-Octyl-4-isothiazolin-3-one
Pentachlorophenol
Potassium 2,4,6-trichlorophenate
2,3,5,6-Tetrachloro-4-methylsulfonyl pyridine
Tetrahydro-3,5-diethyl-2H-1,3,5-thiadiazine-2-thione
Thiabendazole
3,4,5-Tribromosalicylanilide
Tributyltin fluoride
Tributyltin salicylate
2,3,5-Trichloro-4-(propylsulfonyl) pyridine

*Source: EPA; compounds may also have other names.
**Subject to mercurial limitations discussed in Background section.

Table 9. Proprietary Mildewcides with EPA Registration

Commercial Name	Active Chemical	EPA Registration Number	Supplier	Color	Suitability for Paints			
					Oil Base	Latex	Interior	Exterior
Cunilate 2174-NA	Copper 8-quinolinolate	2829-17	Ventron	Yellowish green	Yes	No	Yes	Yes
Cunilate 2174-NO	Copper 8-quinolinolate	2829-44	Ventron	Yellowish green	Yes	No	Yes	Yes
Skane M-8	2-n-Octyl-4-isothiazolin-3-one	707-100	Rohm and Hass	Amber	Yes	Yes	Yes	Yes
Busan 11-M1[a]	Barium metaborate	(FDA 176.180)	Buckman	White	Yes	Yes	Yes	Yes
Onyxide 172	n-Alkyl dimethyl ethylbenzyl ammonium cyclohexyl sulfamate	1839-36	Onyx	White	Some	Yes	Yes	Yes
Tributyl tin oxide	Bis (tributyltin) oxide	2749-11	Aceto	Light yellow	Yes	Yes	No	Yes
Tributyl tin fluoride[a]	Tributyl bin fluoride	2749-54	Aceto	White	Yes	No	Yes	Yes
Super Ad-It	Di(phenylmercuric) dodecenyl succinate	1100-37	Tenneco	Light yellow	No	Yes	No	Yes
Nuodex PMO 10	Phenylmercuric oleate	1100-33	Tenneco	Light yellow	No	Yes	No	Yes
Nuodex PMA 18	Phenylmercuric acetate	1100-56	Tenneco	Light yellow	No	Yes	No	Yes
PMA 60	Phenylmercuric acetate	5388-8-1100	Tenneco	White	No	Yes	No	Yes
Fungitrol 11 and 11-50	Folpet-[N-(trichloromethylthio) phthalimide]	1100-70 and 1100-78	Tenneco	Off-white	Yes	No	Yes	Yes
Metasol TK-100[a]	2-(4-Thiazolyl) benzimidazole	2079-38	Merck	Off-white	Yes	Yes	Yes	Yes
Intercide MDS	Di(phenylmercuric) dodecyl succinate	1100-37-34688	Interstab	Light yellow	No	Yes	No	Yes
Intercide PMO-11%	Phenylmercuric oleate	5388-5-34688	Interstab	Light yellow	No	Yes	No	Yes
Intercide 60 and PMA-18%	Phenylmercuric acetate	5388-8-34688 and 1100-56-34688	Interstab	Light yellow Off-white	No	Yes	No	Yes
Intercide 340-A	Bis (tribytyltin) oxide	34688-9	Interstab	Light yellow	Yes	Yes	Yes	Yes
Intercide TMP	Folpet-[N-trichloromethylthio) phthalimide]	1100-70	Interstab	Off-white	Yes	No	Yes	Yes
Nopcocide N-40-D	Tetrachloroisophthalonitrile	2204-18	Diamond Shamrock	Off-white	No	Yes	Yes	Yes
Nopcocide N-96[a]	Tetrachloroisophthalonitrile	2204-12	Diamond Shamrock	Off-white	Yes	Yes	Yes	Yes
F-21 Fungicide	Dimethyl [4-methyl-1,3-phenylene-his (iminocarbonyl-1H-bensimidazole-1,2-diyl)] biscarbonate	352-377-AA	DuPont		No	Yes	No	Yes
Copper 8-quinolinolate	Copper 8-quinolinolate	10829-8	Tanabe	Yellowish green	Yes	No	Yes	Yes

[a]Pigment that must be dispersed into paint during manufacture.

Table 10. Addresses of Suppliers of Mildewcides

Aceto Chemical Co., Inc.
126-02 Northern Blvd.
Flushing, N. Y. 11368

Buckman Laboratories, Inc.
1256 North McLean Blvd.
Memphis, Tennessee 38108

Diamond Shamrock
Processing Chemicals Division
350 Mt. Kemble Ave.
Morristown, N. J. 07960

E. I. DuPont De Nemours and Co., Inc.
Industrial Chemicals Department
Wilmington, DE

Insterstab
500 Jersey Ave.
P. O. Box 638
New Brunswick, N. J. 08903

Merck Chemical Divison
Merck and Co., Inc.
P. O. Box 2000
Rahway, N. J. 07065

Onyx Chemical Company
190 Warren Street
Jersey City, N. J. 07302

Rohm and Haas Company
Independence Mall West
Philadelphia, PA 19105

Tanabe USA, Inc.
P. O. Box 85132
San Diego, Calif. 92138

Tenneco Chemicals
P. O. Box 365
Piscataway, N. J. 08854

Ventron Division of Thiokol
150 Andover Street
Danvers, Mass. 01923

Figure 1. Mildew defacement of building at Naval Weapons Station Yorktown, VA.

Figure 2. Black algal defacement accelerated by water running down side of building at Guam.

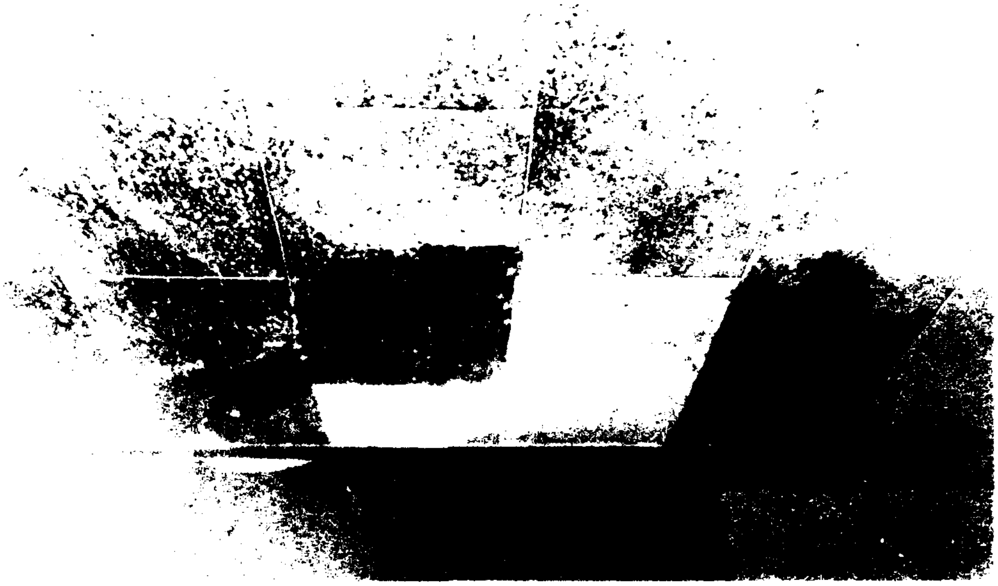

Figure 3. Mildew on interior ceiling tiles at Okinawa.

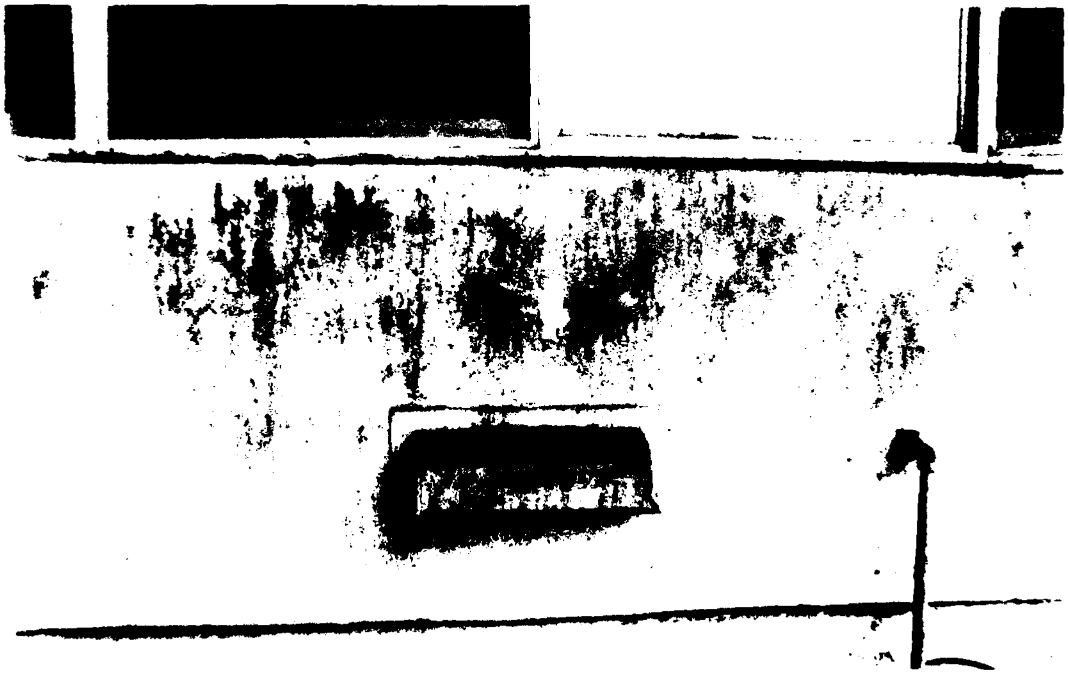

Figure 4. Green and red algal defacement of building exterior at Cubi Point.

Figure 5. Red algal defacement at Guam. Note yellow "+" rubbed into surface by damp finger.

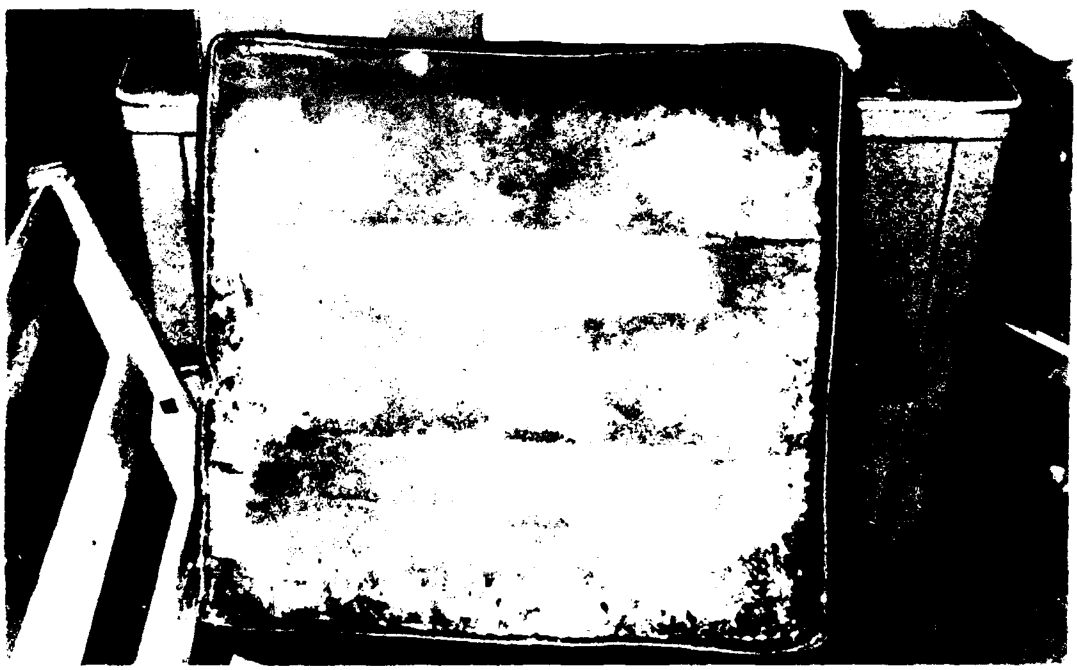

Figure 6. Mildew on plastic seat cushion at Guam.

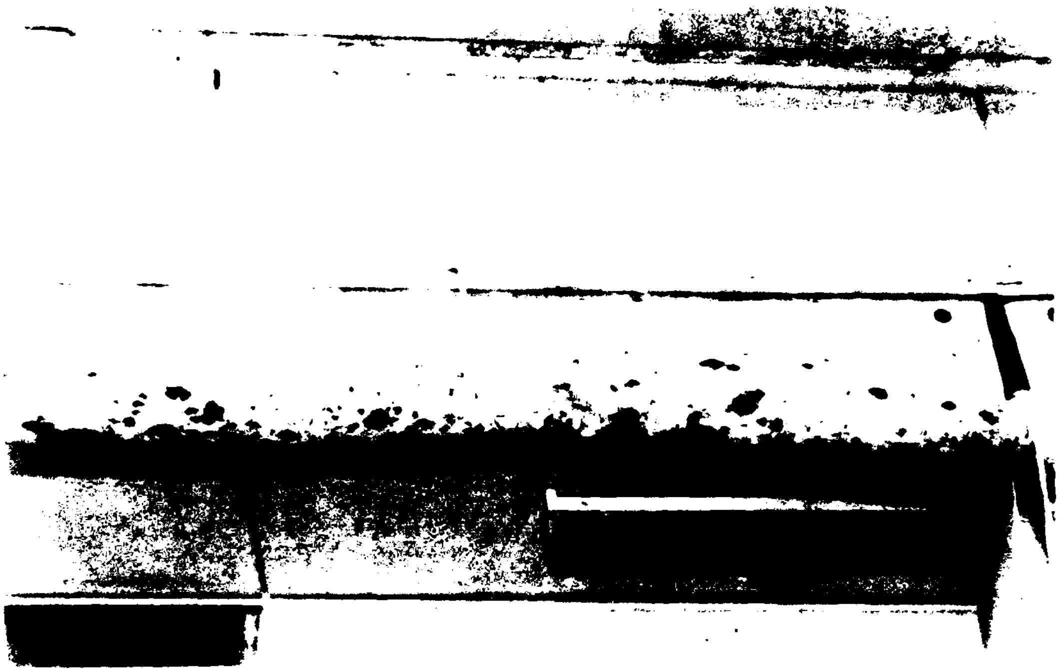

Figure 7. Mildew on canvas awning at Subic Bay.

Figure 8. Mildew under walkway overhead at Guam.

Figure 9. Mildew where water dropped from air conditioner.

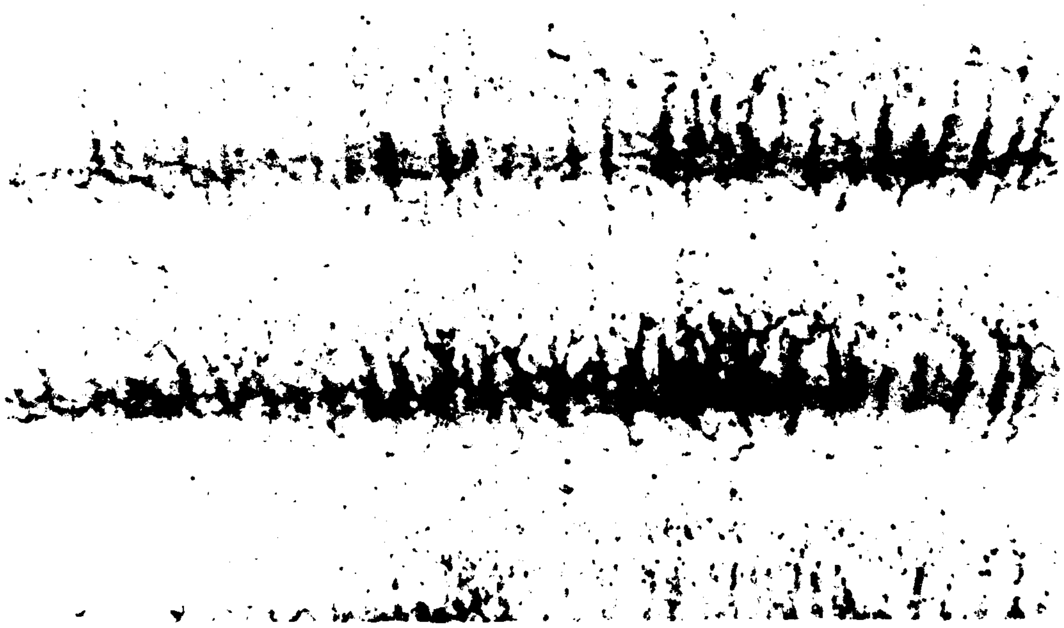

Figure 10. Mildew on wrinkled paint film.

Appendix

RECOMMENDED PRACTICES FOR APPLYING LATEX PAINT TO CONCRETE

The chief advantages and disadvantages of latex paints are listed below:

Advantages	Disadvantages
One-package coating	Limited durability
Moderate cost	Poor chemical and solvent resistance
Good flexibility	Limited wetting of surfaces
Easy to apply, topcoat, repair	Poor immersion resistance
Low organic solvent pollution potential	

When painting the concrete exteriors and interiors of Navy buildings, the advantages of latex paints over their disadvantages generally dictate their use. Latexes (e.g., TT-P-19, TT-P-29, and TT-P-55) are generally of the acrylic or polyvinyl acetate (more often simply called vinyl) emulsion type or a combination of the two. Straight acrylics are believed to provide greater durability than either vinyls or vinyl-acrylics. A chlorinated rubber paint (TT-P-95, Type 1) is used where the wall is to be sealed or receive frequent scrubbing (e.g., in shower rooms). The latex paints permit passage of water vapor (i.e. "breathe") and do not have a high resistance to scrubbing.

One important disadvantage of latex paints is their limited ability to wet smooth surfaces (e.g., enamel on concrete) and their limited ability to penetrate chalky weathered coatings or other surface textures. Thus, special efforts must be taken when these conditions are present. For textured concrete (e.g., porous block), complete coating of surfaces is best achieved through brushing paint into the pores. Masonry fillers can be used on porous surfaces such as rough concrete, concrete block, stucco, and other masonry surfaces to fill open pores and voids by brushing filler material into the surface. The use of two different types of filler coating, one solvent-thinned and the other water-borne, are described in paragraph 4.4.5.3b of Reference 10.

Recommended Practices

1. Make necessary structural repairs/modifications before preparing the surface for painting.

2. Waterblast surface to remove all contaminants or loose, old paint that would inhibit bonding of new paint. Remove loose chalk of old paint so that chalking is rated no less than 8 as indicated in Reference 24. Remove any oil or grease by solvent wiping. Remove any mildew according to Reference 10, paragraph 10.3.2.5.

3. Lightly sand very smooth concrete or paint.

4. Use acrylic paint (e.g., TT-P-19) for maximum exterior durability. Do not use alkyd or other drying oil paints directly on concrete.

5. Brush latex paint in for maximum penetration and coverage of textured surfaces. Do not apply latex paints at less than 50°F. Apply the paint to slightly damp - not wet - surfaces, painting in the shade on sunny days as far as possible. Do not thin paints before application.

DISTRIBUTION LIST

ASO PWO, Phila, PA
ASU PWO, Bahrein
COMFAIRWESTPAC PWO, Misawa, Japan
COMFLEACT, OKINAWA PWO, Sasebo, Japan; PWO, Sasebo, Japan
COMNAVDIST PWO - Hd, Engr Div, Wash DC
DEFENSE DEPOT OGDEN PWO, Ogden, UT
DEFENSE ELEC SUP CEN PWO, Dayton, OH
DTNSRDC PWO Bethesda, MD
FLTCOMBATTRACENLANT PWO, Virginia, Beach VA
MARCORPS AIR/GND COMBAT CTR PWO, Twentynine Palms CA
MARINE CORPS BASE PWO, Camp Butler, Japan; PWO, Camp Lejeune, NC; PWO, Camp Pendleton CA; PWO, Camp S. D. Butler, Kawasaki Japan
MCAS PWO - Santa Ana, CA; PWO, Beaufort, SC; PWO, Cherry Point, NC; PWO, Iwakuni, Japan; PWO, Kaneohe, HI; PWO, Yuma AZ
MCDEC PWO, Quantico, VA
MCLB PWO, Barstow CA
MCRD PWO - Engr Div, Parris Island, SC
NAF CO (Code 32) El Centro, CA; CO (PW), Sigonella, Sicily; PWO, Atsugi Japan; PWO, Mount Clemens, MI
NAS PWO - Engr Div., San Diego, CA; PWO - South Weymouth, MA; PWO Lakehurst, NJ; PWO Point Mugu, CA; PWO Sigonella Sicily; PWO, Alameda, CA; PWO, Beeville, TX; PWO, Belle Chasse, LA; PWO, Cecil Field, FL; PWO, Corpus Christi TX; PWO, Cubi Point, R.P.; PWO, Dallas, TX; PWO, Fallon NV; PWO, Glenview, IL; PWO, Gtmo, Cuba; PWO, Jax, FL; PWO, Key West, FL; PWO, Kingsville, TX; PWO, Lemoore CA 93245; PWO, Los Alamitos, CA; PWO, Marietta, GA; PWO, Meridian, MS; PWO, Millington, TN; PWO, Moffett Field, CA; PWO, Norfolk, VA; PWO, Oak Harbor, WA; PWO, Patuxent River MD; PWO, Rota, Spain; PWO, Virginia Beach, VA; PWO, Whiting Field, Milton, FL; PWO, Willow Grove, PA
NATNAVMEDCEN PWO, Bethesda, MD
NAVACT PWO - Engr Dir, (Code A172), London, UK
NAVACTDET PWO - Eng Dir, Holy Loch, Scotland
NAVADMINCOM PWO Code 50, Orlando FL
NAVAIRDEVCEN PWO, Warminster, PA
NAVAIRENGCEN Code 18 (PWO) Lakehusrt, NJ
NAVAIRPROPTESTCEN PWO - Engr. Div, Trenton, NJ
NAVAL HOME PWO Gulfport, MS
NAVAVIONICFAC PWO, Indianapolis, IN
NAVCOASTSYSTCTR PWO, Panama City, FL
NAVCOMMAREAMSTRSTA PWO - Engr Div, Norfolk, VA
NAVCOMMSTA PWD - Maint. Control Div, Stockton, CA; PWO - Engr Div, Exmouth, Australia; PWO Nea Makri, Greece; PWO, Puerto Rico; PWO, San Miguel, RP
NAVCOMMU CO (Code 04), Thurso, Scotland
NAVCOMMUNIT PWO - Cutler, East Machias, ME
NAVDET PWO, Souda Bay, Crete
NAVEDTRAPRODEVCEN PWO, Pensacola, FL
NAVEDUTRACEN PWO, NAVBASE, Newport, RI
NAVFAC PWO Big Sur, CA; PWO, Antigua; PWO, Brawdy Wales UK; PWO, Coos Head, Charleston OR; PWO, Ferndale, CA
NAVFAC PWO, Lewes, Del.
NAVFAC PWO, Pacific Beach, WA
NAVFACENGCOM - CHES DIV, Contracts, ROICC, Annapolis MD; Wash, DC
NAVFACENGCOM - LANT DIV, Norfolk, VA
NAVFACENGCOM - NORTH DIV, AROICC So. Weymouth, MA; Phila, PA; ROICC, Contracts, Crane IN
NAVFACENGCOM - PAC DIV, Commander, Pearl Harbor, HI
NAVFACENGCOM - SOUTH DIV, CO, Charleston SC
NAVFACENGCOM - WEST DIV, AROICC, Contracts, Twentynine Palms CA; San Bruno, CA
NAVFACENGCOM CONTRACTS AROICC MCAS El Toro; AROICC MCAS, Yuma, AZ; AROICC MCLB Barstow, CA; AROICC NAS, Moffett Field, CA; AROICC NETC Newport, RI; AROICC, Adak, AK; AROICC, Babbitt, NV; AROICC, Code 1042.2, Vallejo CA; AROICC, Dallas, TX; AROICC, Fallon, NV; AROICC, Great Lakes, IL; AROICC, Lajes Air Base, Azores; AROICC, MCAS, Beaufort, SC; AROICC, MCAS, Cherry Point, NC; AROICC, Marcorps Base, Camp Lejeune, NC; AROICC, NADC, Warminster, PA; AROICC, NAF, Sigonella, Sicily; AROICC, NAS, Lakehurst, NJ; AROICC, NAS, Pensacola, FL; AROICC, NATC, Patuxent River, MD; AROICC, NAVSUBBASE, Groton, CT; AROICC, NAVSUPPACT, Naples, Italy; AROICC, NORTHDIV NAS South Weymouth, MA; AROICC,

NORTHDIV Portsmouth Nav Shpyd, Porsmouth, NH; AROICC, NPS, Monterey, CA; AROICC, NPTR, El Centro, CA; AROICC, NRMC, Camp Lejeune, NC; AROICC, NSPCC, Mechanicsburg, PA; AROICC, NWS, Yorktown, VA; AROICC, Oceanside, CA; AROICC, Orlando, FL; AROICC, Panama City, FL; AROICC, Parris Island, SC; AROICC, Point Mugu CA; AROICC, Quantico, VA; AROICC, Whidbey Is, Oak Harbor, WA; AROICC, Yokosuka; Colts Neck, NJ; Contracts, AROICC, Lemoore CA; Dir. of Constr, Tupman, CA; Eng Div dir, Southwest Pac, Manila, PI; Engr. Div. (F. Hein), Madrid, Spain; NAS, Jacksonville, FL; OICC Mid Pacific, Pearl Harbor HI; OICC Trident, Alexandria VA; OICC, (Diego Garcia), Houston, TX; OICC, Guam; OICC, Kins Bay, GA; OICC, NRMC, San Diego, CA; OICC-ROICC, NAS Oceana, Virginia Beach, VA; OICC/ROICC, Norfolk, VA; ROIC; ROICC Code 495 Portsmouth VA; ROICC Key West FL; ROICC NAS, Long Beach, CA; ROICC PONAPE; ROICC Rckwl Intl Columbus, OH; ROICC Rota Spain; ROICC, CHESDIV, Wash., DC; ROICC, Camiso Air Base, Italy; ROICC, Castle AFB, Merced, CA; ROICC, Charleston, SC; ROICC, Clark AFB, RP; ROICC, Code 7002, China Lake CA; ROICC, Diego Garcia Island; ROICC, Griffiss AFB, NY; ROICC, Gtmo, Cuba; ROICC, Indian Head, MD; ROICC, Keflavik, Iceland; ROICC, Kosrae; ROICC, Mombasa, Kenya; ROICC, NAS, Corpus Christi, TX; ROICC, NAS, Millington TN; ROICC, NAVBASE, Phila, PA; ROICC, New Orleans, LA; ROICC, Oakland, CA; ROICC, San Diego, CA; ROICC, Subic Bay, RP; ROICC, Tirrenia, Italy; ROICC, Truk; ROICC, Yap; ROICC-OICC-SPA, Norfolk, VA; ROICC, NCBC, Gulfport, MS

NAVHOSP PWO, Beaufort, SC; PWO, New Orleans, LA; PWO, Puerto Rico

NAVINACTSHIPSTORFAC PWO, Orange, TX

NAVMEDRSCHU 3 PWO , Cairo, UAR

NAVORDSTA PWO Louisville, KY; PWO, Indian Head, MD; PWO, White Sands, NM

NAVPGSCOL PWO, Monterey, CA

NAVPHIBASE PWO Norfolk, VA

NAVRADRECFAC PWO, Kami Seya, Japan

NAVREGMEDCEN PWO - Engr Div, Camp Lejeune, NC; PWO, Charleston, SC

NAVREGMEDCEN PWO, Okinawa

NAVREGMEDCEN PWO, Phila., PA

NAVSCSCOL PWO, Athens, GA

NAVSECGRUACT PWO, Chesapeake, VA; PWO, Edzell Scotland; PWO, Goleta Is., CZ; PWO, Homestead, FL; PWO, Puerto Rico; PWO, Puerto Rico; PWO, Skaggs Is, Sonoma CA; PWO, Torri Station, Okinawa; PWO, Winter Harbor, ME

NAVSECSTA PWO, Wash., DC

NAVSHIPYD PWO - Code 400, Long Beach, CA; PWO, Bremerton, WA; PWO, Charleston, SC; PWO, Long Beach, CA; PWO, Norfolk, VA; PWO, Philadelphia, PA; PWO, Portsmouth NH; PWO, Vallejo, CA

NAVSTA PWO - Supr. Engrng Tech, Argentia, NF; PWO Puerto Rico; PWO, Adak, AK; PWO, Balboa, CZ; PWO, Brooklyn, NY; PWO, Charleston, SC; PWO, Engr Div, Gtmo, Cuba; PWO, Keflavik; PWO, Mayport FL; PWO, Midway Is.; PWO, Phila., PA; PWO, Rodman Canal Zone; PWO, Rota, Spain; PWO, San Francisco, CA

NAVSUBASE CO (Code 223) Bangor, Bremerton, WA; PWO - Engr Div, Groton, CT

NAVSUPPACT PWO, Naples Italy; PWO, New Orleans, LA; PWO, Vallejo, CA

NAVSUPPFAC PWO Diego Garcia I; PWO, Thurmont, MD

NAVSUPPO PWO, La Maddalena, Italy

NAVSURFWPNCEN PWO, Dahlgren, VA; PWO, Silver Spring, MD

NAVUSEAWARENGSTA PWO, Keyport WA

NAVWPNCEN PWO (Code 266) China Lake, CA

NAVWPNSTA PWO Colts Neck, NJ; PWO, Charleston, SC; PWO, Concord CA; PWO, Fallbrook, CA; PWO, Portsmouth, VA; PWO, Seal Beach, CA

NAVWPNSTA-ST JULIENS ANNEX PWO - Engr Div, Portsmouth, VA

NAVWPNSUPPCEN PWO, Crane, IN

NCBC PWO (Code 80) Port Hueneme, CA; PWO, Davisville RI; PWO, Gulfport, MS

NRL Code 1226.1, Washington DC

NSC PWO, Norfolk, VA

NUSC PWO AUTEC West Palm Bch Det, West Palm Beach, FL; PWO, Newport, RI; PWO, Newport, RI

PACMISRANFAC PWO, Barking Sands, HI

PWC CO Norfolk, VA; Commanding Officer; Commanding Officer Great Lakes, IL; Commanding Officer, Guam; Commanding Officer, Oakland, CA; Commanding Officer, Pearl Harbor, HI; Commanding Officer, San Diego, CA; Commanding Officer, Seattle, WA

SPCC PWO - Engr Div, Mechanicsburg, PA

TRIDENT PWO, Bangor, WA

USNA PWO - Annapolis, MD

SANDIA LABORATORIES Seabed Progress Div 4536 (D. Talbert) Albuquerque NM